3. MEASUREMENTS

In this section the measurement procedure is described and representative measurements are summarized.

3.1 Procedure

All measurements were obtained while the van was parked. All doors to the van were closed during measurements to maximize shielding from radio frequency interference (RFI) generated by the NMS equipment. If possible, the van was powered with an ac connection; otherwise the van power inverters were used. After the instruments had warmed up, a series of tests were conducted to ensure the system was operating properly.

First, the antenna was replaced by a 50-ohm load. The log amplifier output was connected to a digital oscilloscope to measure the noise power and determine if any conducted RFI was present. The log amplifier output then was connected to the ADC and one or more noise histograms were collected for calibration purposes. Next, the antenna was reconnected and the preamplifier output was connected to the input of a spectrum analyzer to look for interference.

The measurements were conducted at the 137.5 MHz APT satellite frequency allocation. We chose to operate at this frequency so that the measurements would be protected from other satellite transmitters. We also were able to use the APT signal to verify receiver operation. The satellite was visible every 12 hours when it would make three passes that were 15 minutes in duration, at 100-minute intervals. The frequency modulated satellite signal was evident in the noise power measurement data when mean and median powers rose, converged, fell, and diverged in time intervals corresponding to the three satellite passes. Figure 3.1a illustrates three satellite passes at 5:30 a.m., 7:15 a.m., and 9:00 a.m.

3.2 Representative Noise Measurements

Representative noise power measurements are summarized graphically by showing the median, mean and peak (value exceeded 0.01% of time) powers in dB relative to kT_0b for each measured histogram over time. The median, mean, and peak powers are the bottom, middle, and top curves respectively of these graphs. Noise added by the receiver has not been removed from these values; therefore, the mean corresponds to the measured noise figure, F. All measurements shown were taken from September 1996 to February 1997.

3.2.1 Residential Noise Measurements

The first residential site is located in a Lakewood, Colorado, subdivision built in the 1960's. The nearest business is approximately 1 km away and the nearest major road also is approximately 1 km away. Measurements were obtained over a 4-day period from Friday, November 8, to Tuesday,

November 12. Two complete days, Sunday, November 10, and Monday, November 11, are shown in Figure 3.1.

The two days show similar median, mean, and peak power behavior. The median power was constant throughout both days. The mean power was fairly constant; however, it was occasionally affected by the peak power. During both days, the peak power was constant from 20:00 to 08:00 the next morning; however, during the day the peak power was variable. The drop of the peak power during the day on Monday, November 11 is dramatic in comparison to Sunday, November 10.

The second residential site is located in a Boulder, Colorado, subdivision built in the 1950's. The nearest business is approximately 1 km away and the nearest major road also is approximately 1 km away. Measurements were taken over a 3-day period from Friday, November 15, to Monday, November 18. Two days of measurements are shown in Figure 3.2.

Before 7:00 on November 17, median and mean power were fairly constant. After 7:00 the median, mean, and peak power rose and stayed at the increased level until 10:00 November 18, when the measurement was stopped. The weather on November 16 was snowy, cold, and cloudy while November 17 was clear, warm, and sunny.

3.2.2 Business Noise Measurements

The office park consisted of several four-story office buildings in Golden, Colorado, located between a major interstate highway and a residential area. The electrical distribution lines are buried. Three extended measurements were conducted at the park. The first measurement location was at the edge of the office park near an interstate highway and approximately 200 m from the nearest office building. The measurements began on Friday, November 22, and ended Tuesday, November 26. Figure 3.3a shows the results from Monday, November 25, at this location. At 00:30 median, mean, and peak powers were very low. The peak power increased slightly until 04:00 with very little effect on the mean power. From 04:00 until 15:00 the median, mean, and peak power increased slowly. After 15:00 all three powers decreased.

The next measurement location was in the center of the office park. The nearest office building was 15 m from the receiver, a road was within 10 m of the receiver, and a metal electrical utility closet was located 4 m from the receiver. The measurements began Tuesday, November 26, and ended Friday, November 29. Figure 3.3b shows the results from Wednesday, November 27, at this location. The median and mean power were the highest of the three measurements in the office park. The peak power indicates the noise was more impulsive in the day than during the night. The largest impulses corresponded to the beginning and end of the work day.

The last measurement location was at the edge of the office park near a residential area. The van was parked within 15 m of the office building and about 50 m from the residential area. A large heating ventilation and air conditioning (HVAC) motor was located 5 m from the receiver. The measurements began Friday, November 29, and ended Monday, December 2. Figure 3.3c shows the

results from Saturday, November 30, at this location. From 00:00 to 06:00 there were some large, regularly occurring peak values. This regularity was unique in the office park data set and is conjectured to be due to noise originating from the nearby HVAC motor.

The first downtown site was located at the intersection of 13th Street and Pearl Street in downtown Boulder, Colorado. This location is surrounded by one- and two- story office buildings and streets with heavy traffic. The measurement was conducted with inverter power because no ac connection was available.

The measurement, shown in Figure 3.4a, lasted approximately 3 hours from 11:40 to 14:40 Wednesday, November 20. The peak power was variable while the median and mean were fairly steady.

The second downtown site included three different locations in downtown Denver, Colorado. The longest duration measurement was obtained at the corner of 17th and Lawrence Street. This location is characterized by tall buildings and streets with heavy traffic. The measurement was conducted with inverter power because no ac connection was available.

The measurement, shown in Figure 3.4b, lasted approximately 3 hours from 10:15 to 13:15 on Tuesday, December 3. Median, mean, and peak power were very similar to those obtained in downtown Boulder, Colorado.

3.2.3 Rural Noise Measurements

Rural mountain noise levels were measured in a steep canyon near Ward, Colorado. At the measurement location there were no visible power lines or houses. A few cars passed by while the measurement was taken. The measurement, shown in Figure 3.5a, was conducted between 10:00 and 11:00 on Thursday, December 5. The results are characterized by constant median, mean, and peak power.

Rural plains noise levels were measured in rural eastern Colorado. The location is characterized by the absence of houses and power lines. Nearby roads have little or no traffic. The measurement was conducted with inverter power because no ac connection was available. The measurement, shown in Figure 3.5b, was conducted on Friday, December 6, from 13:15 to 15:15. The measurement shows fairly constant median, mean, and peak values. Rural plains values were very similar to rural mountain values.

3.2.4 Automotive Noise Measurement

Automotive ignition noise was measured on a road passing through Clear Creek Canyon between Golden, Colorado, and Black Hawk, Colorado. We parked the measurement van along the road at a place in the canyon with steep walls and no power lines or buildings so that we could be reasonably sure the only noise measured originated from automobiles. The measurements were conducted with

inverter power since no ac connection was available. The measurement, shown in Figure 3.6, was collected on Thursday, November 21, between 13:00 and 15:00. Median and mean values were fairly constant, while peak values varied.

3.2.5 Electrical Network Noise Measurement

Electrical utilities generate, transmit, and distribute electrical power throughout most business, residential, and rural areas. The transmission generally is performed at high voltage levels while distribution of the electrical power to buildings is performed at lower voltage levels. The noise attributed to the electrical network is generated by corona and gap discharge phenomena and has been studied for many years [12].

Noise from electrical transmission and distribution was measured on a lightly traveled road located between Highway 93 and the small town of Leyden, Colorado. A high-voltage transmission line runs perpendicular to this road, while a low-voltage distribution line runs parallel to the road. The road is located in the bottom of a gently sloping valley. The measurements were obtained with inverter power because no ac connection was available.

Three measurements, shown in Figure 3.6, were obtained along this road on Tuesday, November 12. The first measurement, obtained directly under the high-voltage line from 13:30 to 14:00, showed low mean powers. The second measurement, obtained about 70 m from the high-voltage transmission line from 14:30 to 15:30, was similar to the first. The third measurement; however, conducted approximately 2 km from the high-voltage transmission line from 15:45 to 16:30, showed a mean and peak power 15 to 20 dB higher than the previous two measurements. The third measurement was obtained in close proximity to an electrical distribution device mounted on a wooden pole.

3.2.6 Electronic Equipment Noise Measurement

Electronic equipment has proliferated since similar noise measurements were undertaken in the 1970's. Microprocessors with clock speeds of hundreds of MHz are embedded in many consumer items, not the least of which is the ubiquitous personal computer. During the measurement campaign we observed electronic equipment noise that was both broadband and narrowband in comparison to the bandwidth of the final IF filter of the measurement receiver.

The noise from two computers was measured in a relatively quiet area located in the Plainview Open Space near Boulder, Colorado. The computers tested were placed about 3 m from the receiving antenna. Three measurements, shown in Figure 3.8, were taken on Tuesday, December 10. First, noise from a 20-MHz clock speed personal computer was measured from 14:15 to 14:45; next, a background measurement without computers was obtained from 14:45 to 15:15, and last, noise from a 50-MHz clock speed personal computer was measured from 15:30 to 16:00.

These measurements show that computer noise varies considerably. These spikes in the mean and peak power of the background measurement were observed at other times at this location. We assumed it was coincidence that they were not present when either of the two computers was measured.

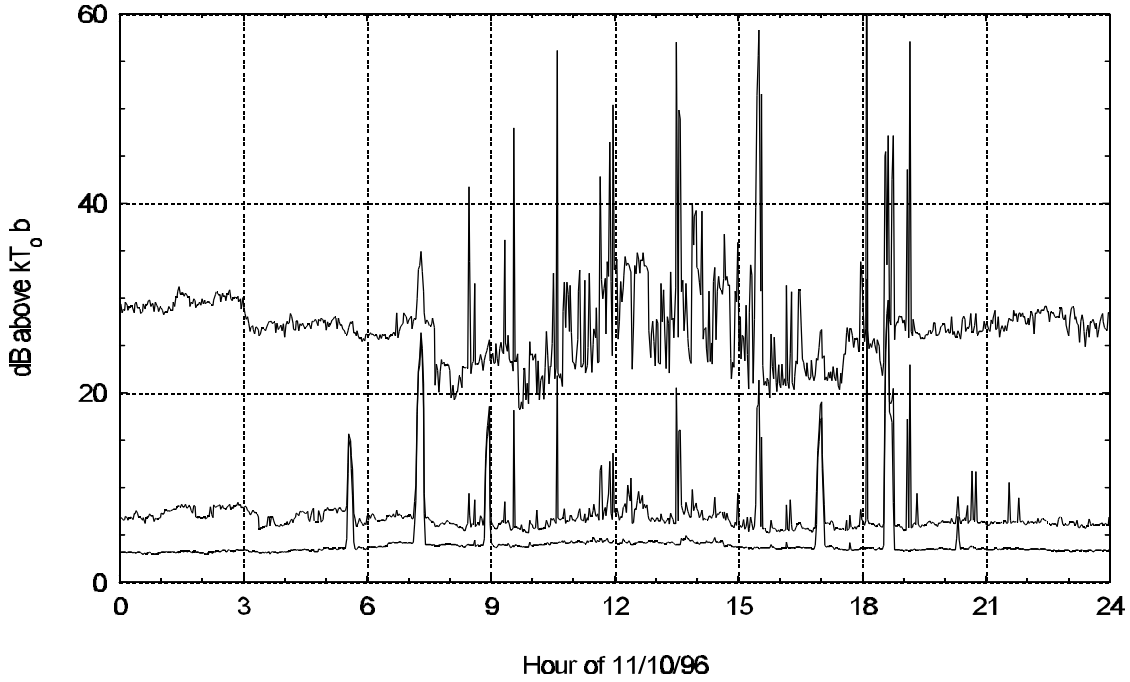

Figure 3.1a Median, mean, and peak power at Lakewood, Colorado, residence on November 10, 1996.

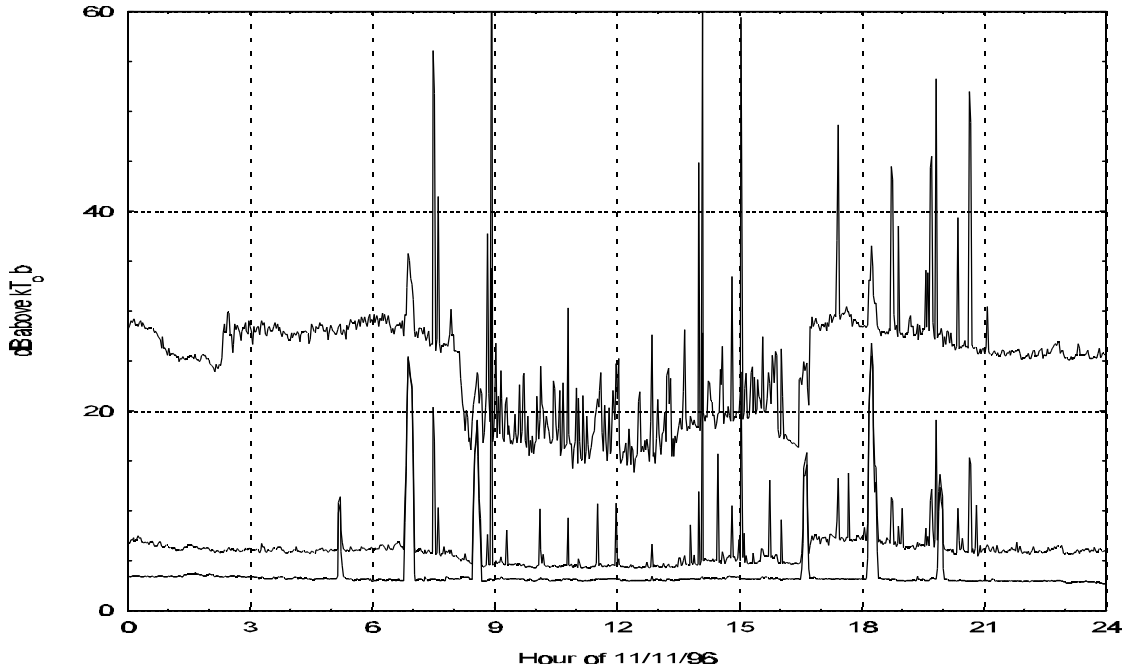

Figure 3.1b Median, mean, and peak power at Lakewood, Colorado, residence on November 11, 1996.

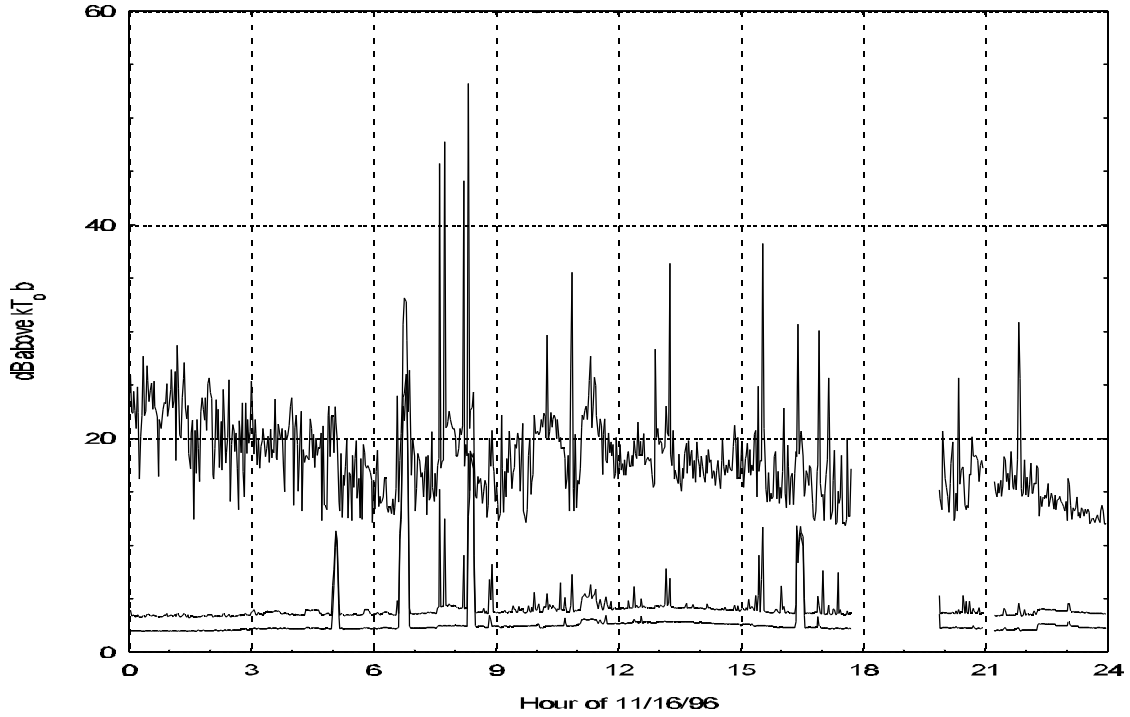

Figure 3.2a Median, mean, and peak power at Boulder, Colorado, residence on November 16, 1996.

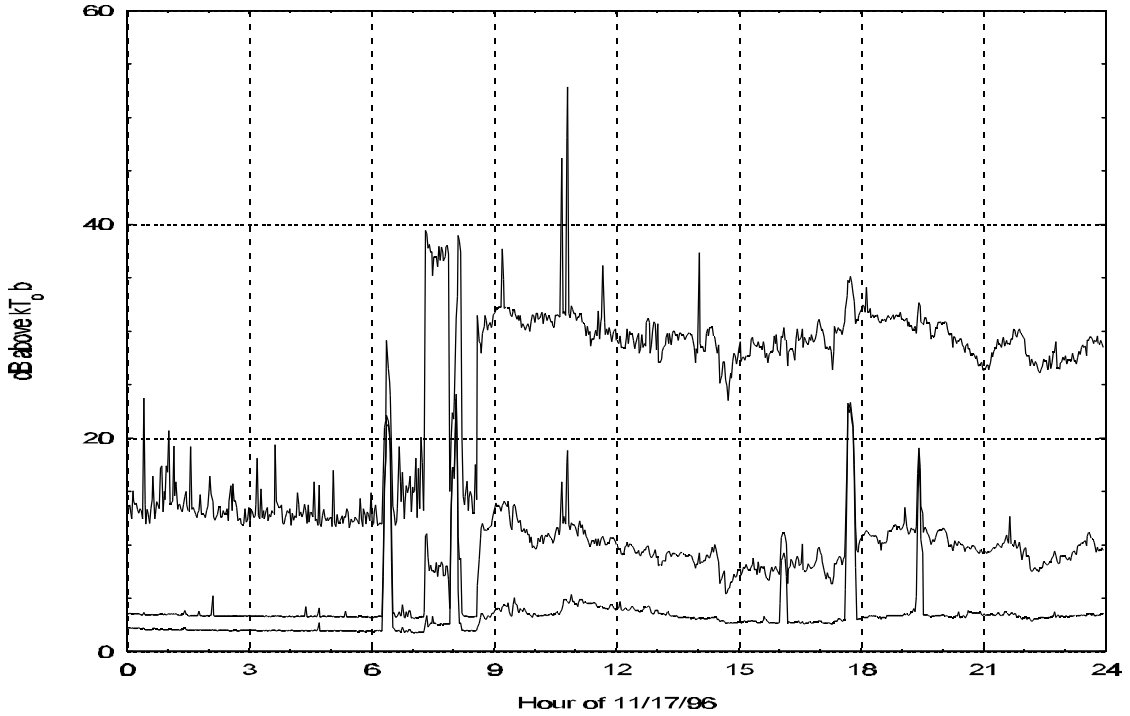

Figure 3.2b Median, mean, and peak power at Boulder, Colorado, residence on November 17, 1996.

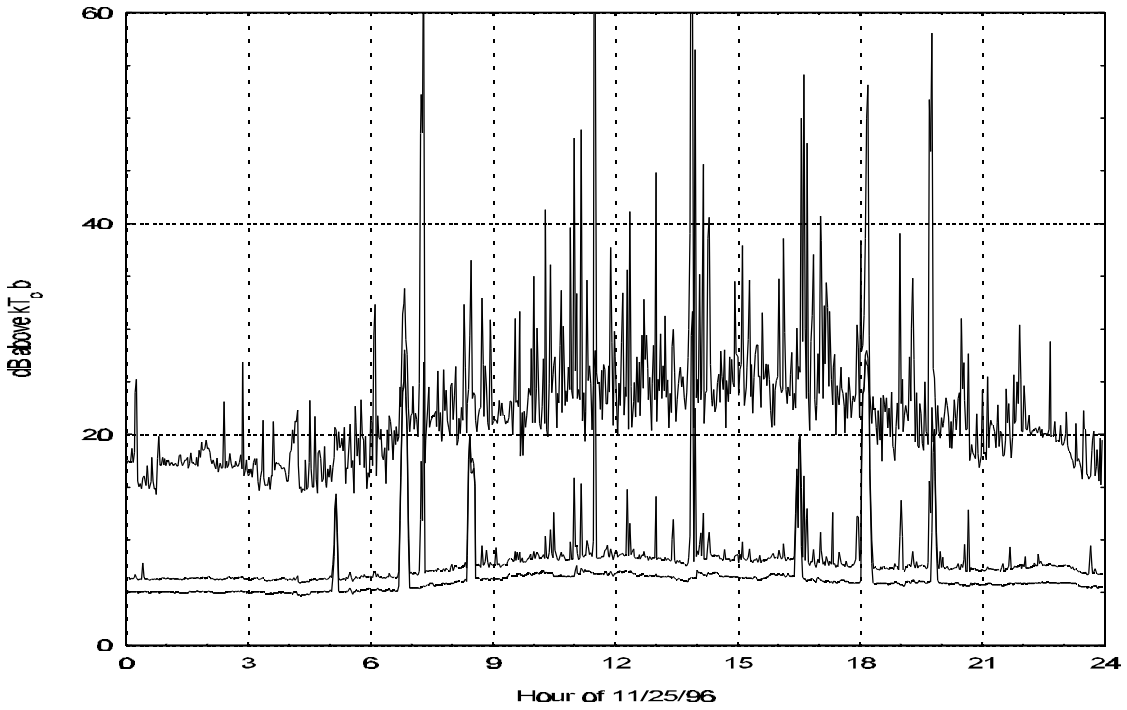

Figure 3.3a Median, mean, and peak power at edge of office park site near interstate highway on November 25, 1996.

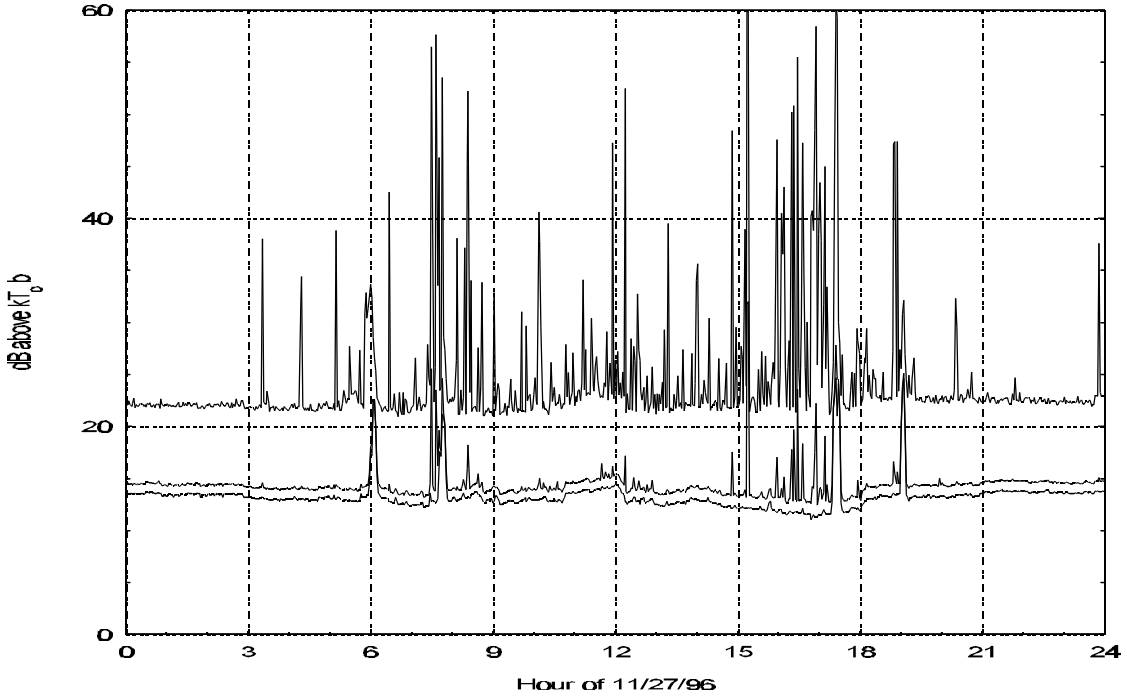

Figure 3.3b Median, mean, and peak power at center of office park site on November 27, 1996.

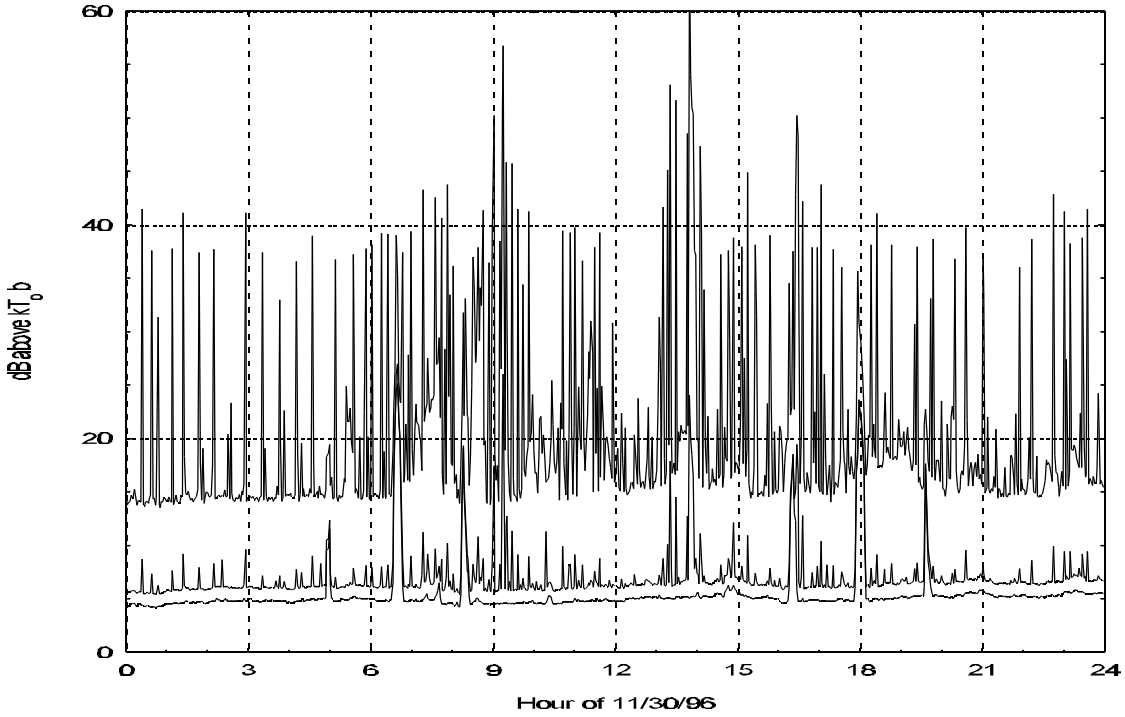

Figure 3.3c Median, mean, and peak power at edge of office park site near residential area on November 30, 1996.

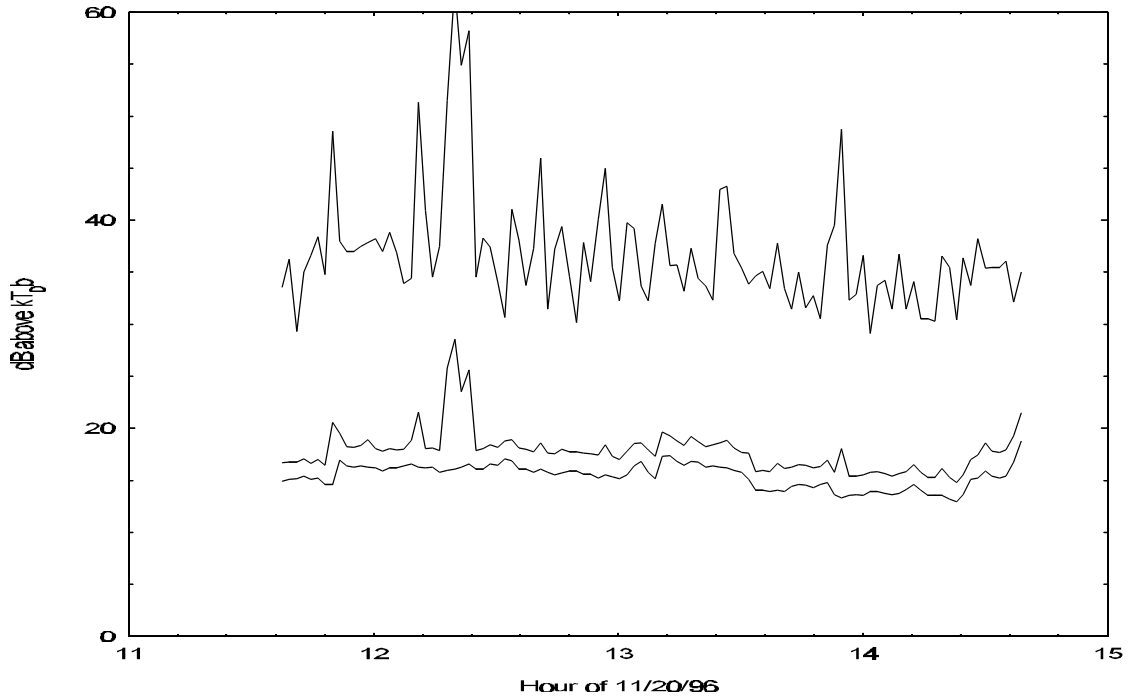

Figure 3.4a Median, mean, and peak power at downtown Boulder, Colorado, site on November 20, 1996.

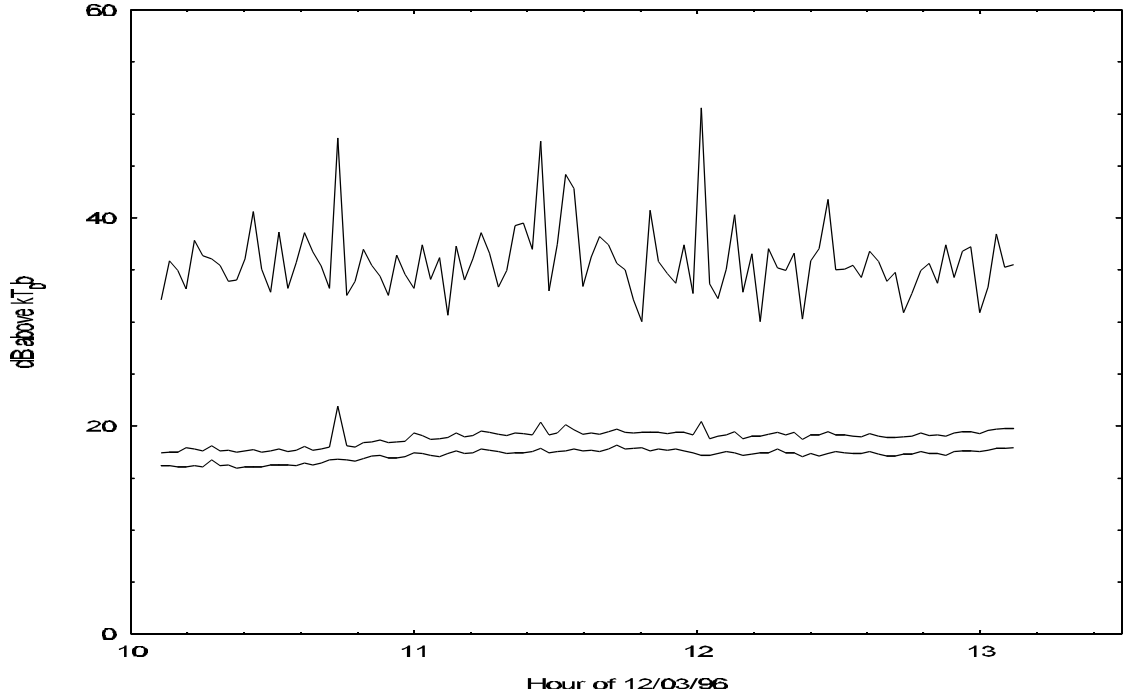

Figure 3.4b Median, mean, and peak power at downtown Denver, Colorado, site on December 3, 1996.

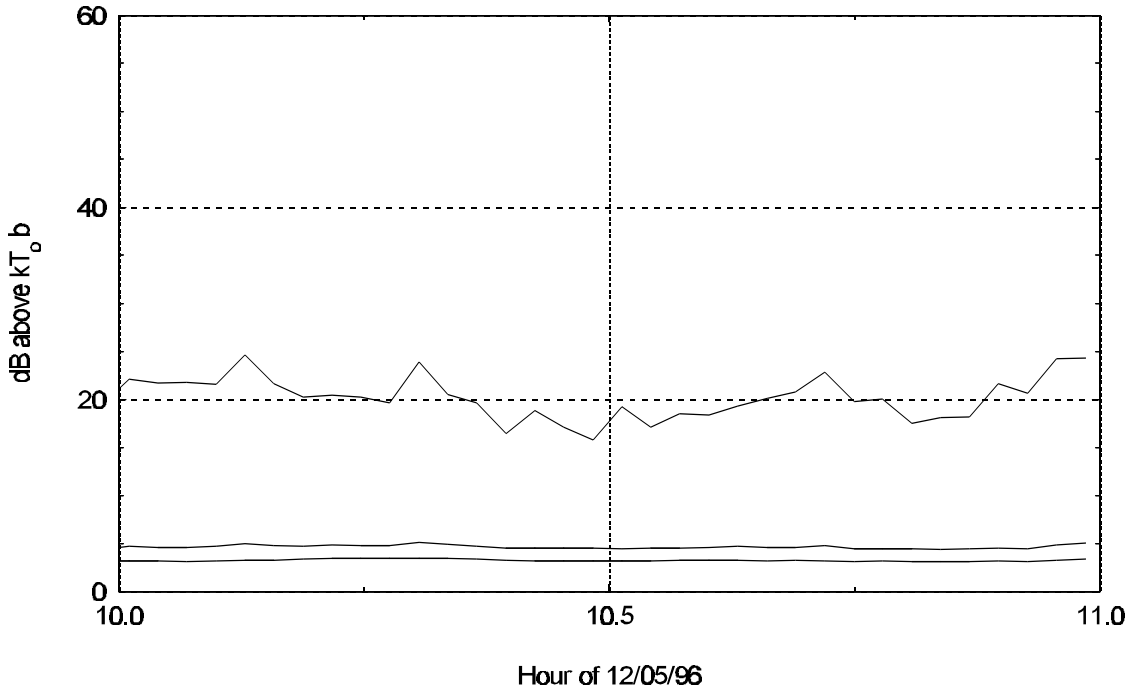

Figure 3.5a Median, mean, and peak power at rural mountain site near Ward, Colorado, on December 5, 1996.

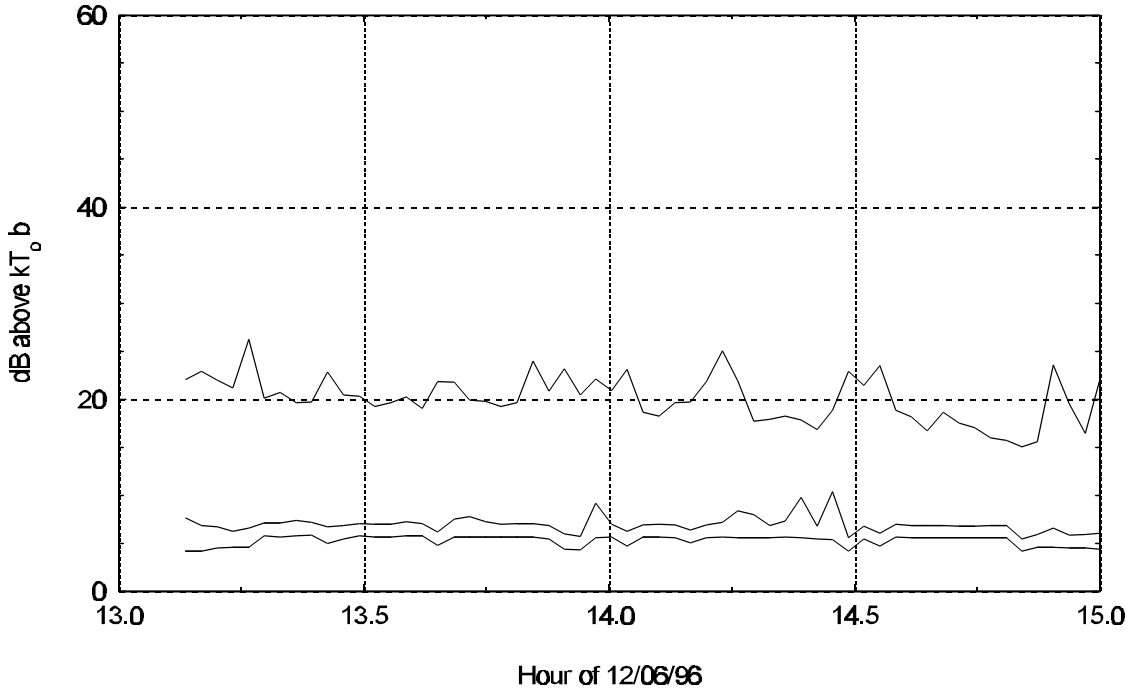

Figure 3.5b Median, mean, and peak power at rural plains site in eastern Colorado on December 6, 1996.

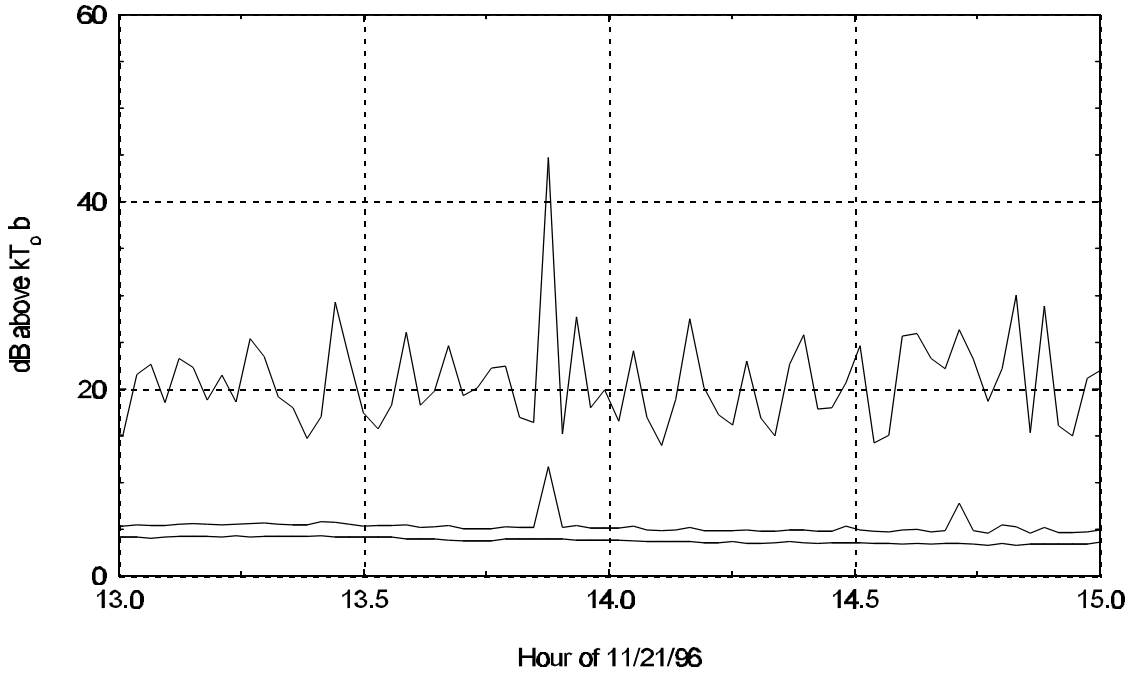

Figure 3.6 Median, mean, and peak power of automobiles measured in Clear Creek Canyon, Colorado.

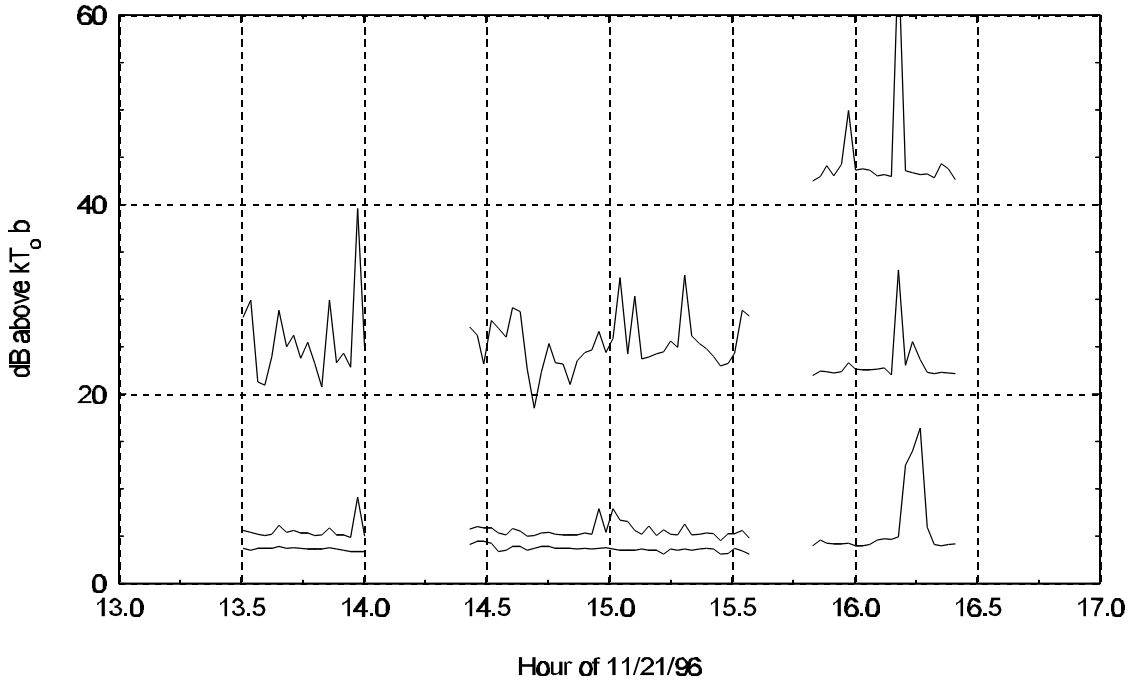

Figure 3.7 Median, mean, and peak power of electrical network measured near Leyden, Colorado.

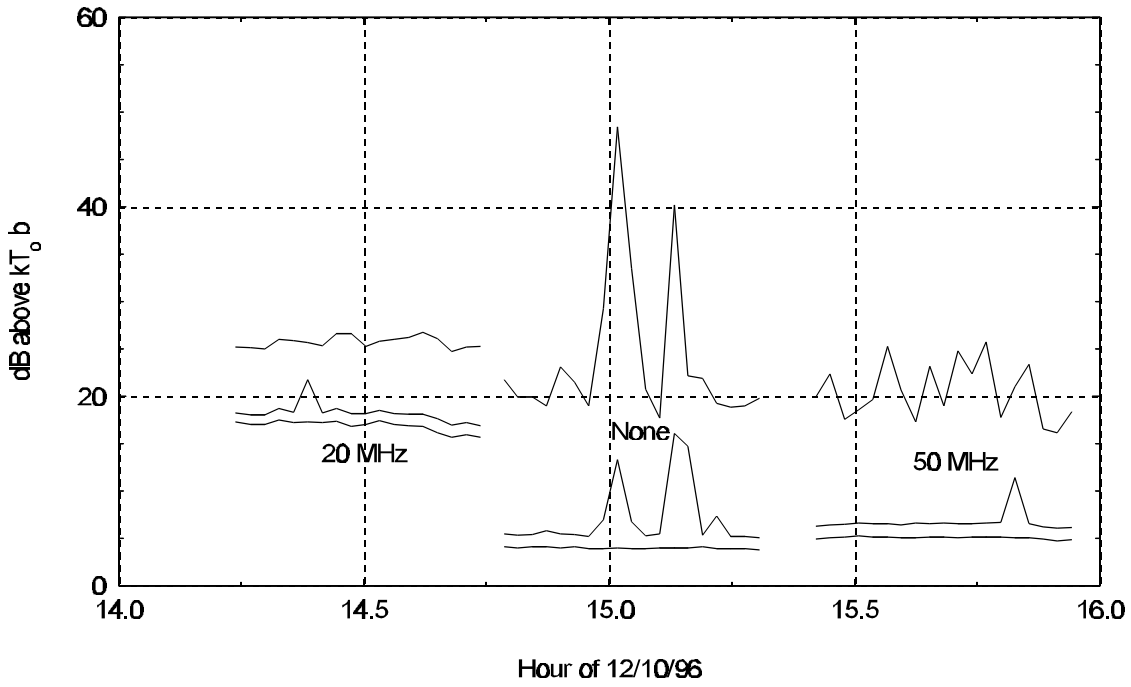

Figure 3.8 Median, mean, and peak power of computers measured at Plainview Open Space near Boulder, Colorado.